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California is now the sixth largest economy in the world, with a gross state product in 2005 of $1.6 trillion. Water exported from the Sacramento–San Joaquin Delta (Delta) plays a major role in sustaining the California economy. Utilities and transportation that pass through the Delta and Suisun Marsh also contribute to the statewide economy and especially to the greater San Francisco Bay Area. The Delta itself is a distinct region with its special lifestyle, economic activities, and recreational opportunities. The towns and cities on the fringes of the Delta are growing rapidly as bedroom communities for nearby cities and for the Bay Area. The Delta and Suisun Marsh also support a wide variety of aquatic and terrestrial species.

The purpose of this section is to describe what is at risk due to levee breaches and island flooding in the Delta. We do not intend to provide a complete Delta overview, nor a detailed inventory in this section, but we do want to provide summary information about the assets in the Delta and also activities outside the Delta that may be affected by levee breaches. Delta Vision has prepared a report on the "Status and Trends of Delta – Suisun Services" (URS 2007). Many other Delta inventories, overviews, summaries, and assessments are referenced in the Status and Trends Report and thus have influenced this section. Readers who want more extensive detail can access it by referring to the Status and Trends Report and its references.

5.1 POPULATION

One can view the populations influenced by the Delta and Suisun Marsh in many different ways. The 2000 census shows that the Delta islands and tracts had a population of about 26,000 people. These are the people who would have the most difficulty with evacuation in the event of levee failures because road access to most areas requires passing over bridges, riding on auto ferries, driving through low-lying areas that may be flooded, and traversing roads on the tops of levees.

The 2000 census also shows that the area protected by levees that are within the legal boundary of the Delta and the Suisun Marsh contains a population of about 470,000 people. The protected area includes portions of urban areas such as West Sacramento, the Pocket Area in Sacramento, and parts of Stockton and Tracy. Some portions, especially in West Sacramento and the Pocket Area are outside the legal Delta but are protected by Delta levees. Most of the residents of these areas would not be subject to flooding from a levee failure at the mean higher high water (MHHW) level (e.g., in the context of most earthquakes), but could be affected by levee failures during a flood with a recurrence interval of 1 in 100 years or higher (see Economic Consequences Technical Memorandum [TM] [URS/JBA 2008f]).

Six California counties have land within the legal Delta. Sacramento, San Joaquin, Solano, Contra Costa, and Yolo counties have portions of both the Delta Primary Zone and the Secondary Zone. Alameda County has a portion of only the Secondary Zone. The combined population of the six counties is about 3.3 million based on the 2000 census and 5.1 million in 2005 (DOF 2007a; U.S. Dept. of Commerce, BEA 2008).

The Delta's importance extends beyond the Delta counties and is directly relevant to the well being of many people in the Greater San Francisco Bay Area, with its population of 7.2 million. Together with the Delta counties not included in the Bay Area, this amounts to a total population of 9.4 million. These people's standards of living and conveniences are directly influenced by Delta-Suisun services including highways, railroads, recreational opportunities, and a host of less obvious utilities.

East Bay Municipal Utility District's (EBMUD's) Mokelumne Aqueduct crosses the Delta, bringing water from the Sierra to serve 1.3 million people in the Bay Area. About 500,000 more people in the Contra Costa Water District use water diverted from the Delta. Finally, the Federal Central Valley Project and the State Water Project, which draw water from the Delta channels, are key water suppliers to several other parts of the Bay Area, including the Santa Clara Valley ("Silicon Valley"), Tracy, the Livermore/Pleasanton area, San Benito County, and communities in the northern Bay Area served by the North Bay Aqueduct. Electrical transmission lines and natural gas pipelines also cross the Delta, delivering these commodities to Bay Area homes and businesses.

Many California residents further to the south of the Delta and Suisun Marsh have never heard of the region, although they also are highly dependent on water withdrawn from the Delta and delivered by the state and federal projects to their communities. About 18 million people served by the Metropolitan Water District of Southern California count on the Delta as part of their drinking water supply. Many other water agencies and districts could have a portion of their supplies interrupted by Delta levee failures. In all, about 27 million people in California currently have water supplies that could be affected by Delta levee failures. Millions of additional people in Northern California and Nevada could have natural gas or petroleum supplies affected by levee failures in the Delta because pipelines carry these products across the Delta.

Considering that a Delta levee failure could affect the economy of California, practically all of the state population has an interest in the Delta. The 2005 population of the state was about 37 million people and it is growing rapidly.

5.2 DELTA LAND USE

Most of the Delta is agricultural land and most of the Suisun Marsh is managed wetlands and other lands managed for conservation. The "Status and Trends Report" (URS 2007) provides the following key points on Delta land use:

- Out of almost 840,000 acres, the 2004 land use consisted of about 9 percent urban, 67 percent agricultural, 14 percent conservation and other open lands, and 10 percent water. A land use map is shown on Figure 5-1.
- Highly productive agriculture occurs on more than 500,000 acres in the Delta, taking advantage of the rich organic (peat) soils to produce high value crops such as fruits and vegetables.
- The organic soils are vulnerable to decomposition and other losses, resulting in subsidence of the ground surface. Elevation losses of 0.5 to 1.5 inches per year have been common, particularly with traditional agricultural practices. As a result, in most Delta land surface elevation lies below sea level, some by as much as 15 to 20 feet.
- About 40,000 acres of land-use conversions from agriculture to urban and conservation uses (approximately half to each) have occurred between 1990 and 2004.
- The Delta Protection Act limits urban growth in the Delta Primary Zone (see Figure 2-3, which shows the area within the Primary Zone).
- The Suisun Marsh Preservation Act also limits urban growth in its Primary Management Area.

- The Secondary Zone of the Delta and the areas immediately adjacent to the Delta and Suisun Marsh are subject to urban development pressures. They are some of the fastest-growing areas of California, particularly near Sacramento, Stockton, Manteca, Tracy, Brentwood/Antioch, and Fairfield/Suisun City.

5.3 ECOSYSTEM

The Delta and Suisun Marsh provide habitat for a diverse estuarine community including fish, wildlife, and aquatic and terrestrial plants. Several unique habitats supporting diverse ecologies exist in the Delta and Suisun Marsh including vernal pool habitat and the marsh/upland transition zone, which is an area of high biodiversity of plants and wildlife. Many endemic species occur in the Delta, including many species of vascular plants in vernal pool habitat, and species of fish including delta smelt. The estuarine ecosystem supports extensive recreational fishing, bird watching, aesthetic enjoyment, and commercial fisheries.

Over the past 150 years, the fish and wildlife communities inhabiting the Delta and Suisun Marsh have lost access to upstream habitat because of a number of factors including construction of dams and impoundments, land use changes, reclamation and channelization/levee construction, exotic species introductions, water diversions with changes in seasonal hydrologic patterns, and other changes. As a result of these and other factors, many of the species in this area have experienced substantial declines in abundance and geographic distribution, leading to the listing of several species under the California and/or federal Endangered Species Acts and the identification of others as species of special concern. Table 5-1 provides a listing.

Levees in the Delta and Suisun Marsh have distinct differences in stature and function. Those differences are relevant to predicting the response of vegetation and animals to levee failure. In the Delta, levees are more robust in stature (e.g., heights up to 20 feet) and support an extensive infrastructure (e.g., paved roads, pipelines, electrical transmission, rail lines). Although Suisun Marsh was originally diked to allow draining for agriculture, the dikes were later altered to facilitate managed flooding to support wildlife habitat consisting of marsh and aquatic vegetation (Chappell 2006). Levees in Suisun Marsh include exterior levees (>9 feet high), and a network of shorter interior levees (>4 feet high) that allow for spatially complex controlled flooding regimes to cultivate different marsh habitats.

Over the past several years many of the pelagic fish species inhabiting the Delta and Suisun Marsh, such as delta smelt and longfin smelt, have experienced a significant decline in abundance, referred to locally by regulatory agencies, scientists, and stakeholders as the pelagic organism decline (POD). The forces contributing to the POD are hypothesized to include changes in seasonal hydrology (due to long-term climatic changes and water export project operational changes), competition from or predation by introduced species, exposure to toxic substances (especially pesticides), and other factors (Armor et al. 2006).

California and federal resource agencies are actively investigating the significance of these and other factors affecting pelagic fish species, their population dynamics, habitat suitability, and the overall condition of the Delta and Suisun Marsh. To date, the relative importance of each of these factors on populations of pelagic species has not been determined. Discriminating direct impacts and interactions among the multiple potential drivers of the POD is difficult, and contributes to the uncertainty surrounding predictions of future states of the estuary's aquatic ecosystems.

The Delta and Suisun Marsh ecosystem supports a high diversity of resident and migratory wildlife, including birds, mammals, reptiles, and amphibians. Until European settlement, the Bay-Delta was dominated by tidal marsh, with extensive riparian forests distributed along the floodplains of its tributaries. Today, the species composition, distribution, and abundance of wildlife in the Bay-Delta are determined primarily by the distribution and extent of the communities that support their habitats.

The major changes in Delta and Suisun Marsh habitats from historical conditions have been the loss of tidal influence with construction of levees and dikes and the conversion of marsh and riparian communities to agricultural uses. Consequently, the distribution and abundance of resident marsh- and riparian-associated species has declined (e.g., California black rail, salt marsh harvest mouse, western yellow-billed cuckoo). The distribution and abundance of species for which agricultural lands provide habitat have been less severely affected or benefited (e.g., wintering waterfowl, raptors).

In addition to resident wildlife, the Bay-Delta serves as a wintering and migration stopover habitat for a large number of waterfowl, sandhill cranes, and shorebirds of the Pacific Flyway. Bay-Delta habitats (e.g., marshes, tideflats, and agricultural lands) provide these species with the food resources needed to sustain their populations during winter, and the energy reserves necessary to sustain migration and initiate breeding on their nesting grounds.

The primary ongoing threats to wildlife habitats in the Delta are those related to loss and degradation of habitat. Such threats include the following:

- Changes in salinity or other water quality parameters that could effect a change in vegetation communities that support existing habitats
- The potential for conversion of agricultural and managed wetland habitats that support large numbers of wintering waterfowl and other birds that winter or migrate through the Delta to habitats that provide lower forage production or to other uses (e.g., development)
- The permanent loss of these habitats due to catastrophic levee failures

5.4 ECONOMY

As with population, several regional economies (and the economy of the whole state) are influenced by the Delta-Suisun area and the integrity of its levees.

Delta Area. The area protected by Delta levees includes about 15,900 businesses that are counted by the ESRI database (PBS&J 2006). These businesses have sales of about $35 billion annually and employ 205,000 people. Table 5-2 summarizes the study area economy in terms of value of sales and employment by sector. Note that much of this economic activity is situated in Sacramento and West Sacramento on land that is outside the legal Delta but could be flooded by the failure of levees located in the Delta. Of course, each of these businesses is vulnerable to direct economic impacts if a levee failure were to result in flooding of their particular island or tract.

Greater San Francisco Bay Area and Delta Counties. Economic activity in a much wider area could be impacted by a major levee failure event in the Delta, including impacts through disruption of water supplies, electrical and natural gas transmission, petroleum product deliveries, recreational opportunities, and multiple modes of transportation. Table 5-3 provides key economic information for the state and the Greater Bay Area, including the three Delta counties not included in the Bay Area (Sacramento, San Joaquin, and Yolo) and for the Delta counties and the Greater Bay Area separately.

The Greater Bay Area and the Delta counties contain more than one fourth of the populations and employment in the state and generate nearly one third of the state's personal income. Intensive service disruptions for this region as the result of a major Delta levee breach event would be bound to affect economic productivity. This would add to the direct impacts of flood damage.

State. The state economy might see major disruptions of water deliveries, affecting most south-of-the-Delta agriculture and all urban areas that receive water supplies from the Delta, including essentially all of southern California. This would be in addition to whatever state economic participation occurred for restoration expenditures and the obvious economic impacts to the state of the disruptions that are more specific to the local area and nearby region.

These prospective economic consequences are discussed in more detail in Section 12 together with the method used to estimate actual numbers for a given levee breach event. More detail on the infrastructure that resides in the Delta is presented below to provide the basis for understanding these regional and statewide economic consequences.

5.5 INFRASTRUCTURE

A large amount of infrastructure is located within the Delta and Suisun Marsh. Some of the infrastructure that crosses the Delta to other parts of California provides vital resources such as water, gas, power, communications, shipping, and railroad freight transportation. By infrastructure, we mean the physical assets that have been constructed or shaped in the Delta to enhance the human environment and provide services. This generally excludes ecosystem features although they are important assets of another type. Also, two aspects of Delta infrastructure are so all-encompassing and pervasive as to be easily overlooked in the summary that follows. These are:

- The Delta levee system – This is a system of man-made embankments that defines the Delta's land/water character. This is clearly infrastructure. It is addressed more specifically in following sections and in the Levee Vulnerability TM (URS/JBA 2008c).
- The Delta channel system that serves as a conveyance route for state, federal, and other water supply – This is also infrastructure, since it is defined by and functions due to the levees, even though it functions in a somewhat passive manner. It is invaluable in transporting water from Delta inflow sources (primarily the Sacramento River) to the state and federal pumping plants (identified as point infrastructure assets) and to the widely dispersed in-Delta water users. The Delta conveyance system is addressed comprehensively in the Water Analysis Module TM (URS/JBA 2007e).

The more commonly known elements of Delta infrastructure can be divided into linear and point assets. Linear infrastructure includes railroads, highways, shipping channels, transmission lines, aqueducts, and gas and petroleum pipelines. Point infrastructure includes bridges, marinas, natural gas fields/storage areas, natural gas wells, commercial and industrial buildings, residences, and pump stations. Although the Delta levees themselves are infrastructure assets, they are not itemized here.

The descriptions of the Delta assets that follow are summarized from information collected in 2004–2005 for the In-Delta Storage Project (URS 2005), from information collected from asset owners (from meetings, telephone conversations, and reports), HAZUS-MH MR2 (FEMA 2006), and from information provided by the California Department of Water Resources (DWR). It has been documented in detail in the Impact to Infrastructure TM (URS/JBA 2007f). The information was then used as described in Section 12 to estimate direct and loss-of-use damages in the context of any specific levee breach event.

5.5.1 Linear Assets

Pacific Gas and Electric Company (PG&E) Natural Gas Pipelines (Figure 5-2 [Proprietary information. Publication not permitted.])

The main PG&E natural gas pipelines that were considered for infrastructure damage estimates are:

- Backbone Line (L400/401): west side of Delta running north-south, 26- to 42-inch outside diameter (OD).
- Line 196: traverses east to west through the middle of the Delta, 12- to 16-inch OD; mostly 16-inch OD.
- Line 108: east side of Delta running north-south, 16- to 24-inch; mostly 24-inch OD.
- StanPac (Standard Oil, now Chevron, and PG&E) Line: west side of Delta, 10- to 16-inch OD.
- Line 57A (18-inch OD) and Line 57B (22-inch OD) from the McDonald Island Gas Storage Field. Line 57C (24-inch OD), which will be 4.7 miles long, is under construction in 2007 (PG&E 2005). This new line will provide redundancy for gas delivery from the gas storage field.

PG&E has used several methods for installing gas pipelines at water crossings, and these include the following:

- Exposed “overhead crossings”: generally used at shorter ditch crossings.
- Hung-on-bridge crossings: very limited use due to required permissions involved and limited availability.
- Trenching: widely used for short to river-wide lengths in which a pipe was originally installed approximately 5 feet deep following the contours of the levee and streambed with a concrete water-break-wall on the top of the levee.
- Horizontal Directional Drilling: Initiated in the mid-1970s and widely adopted in the mid-1980s for water crossings.

PG&E Electrical Transmission Lines (Figure 5-3)

The transmission lines for 500-, 230-, and 115-kilovolt (kV) voltage levels within the Delta and Suisun Marsh areas are constructed on tower structures (some 115-kV lines are on wood poles). Most of the towers have augered footings with a minimum diameter of 2 feet and are installed at various depths. Only about 10 percent of the towers are on pile foundations.

- The 500-kV transmission lines are constructed on single-circuit tower structures. The depths of the footings range from 9 to 15 feet.
- The majority of the 230-kV transmission lines are constructed on double-circuit tower structures. The depths of the footings range from 9 to 20 feet.
- The majority of the 115-kV transmission lines are constructed on double-circuit tower structures. The depths of the footings range from 7.5 to 12.5 feet. Some of the 115-kV lines are constructed on wood poles. The wood pole standards show that the typical depths of the pole settings range from 5 to 10 feet.
- Almost all the 60-kV transmission lines are constructed on wooden poles. The classes and settings of wood poles are designed to meet or exceed the minimum requirements of General Order 95. The pole-setting depths of wood poles vary from 5 to 10 feet depending on the height of the wood poles. Some of the 60-kV transmission lines are constructed on tubular steel poles. The typical foundation size for tubular steel poles at this voltage level is about 4.5 feet in diameter and 17 feet deep.

Information in the Levee Vulnerability TM (URS/JBA 2008c) indicates that major transmission lines are outside the areas of significant peat and organic marsh deposits, except for the transmission lines across Sherman Island.

Highways and Roads (Figure 5-4)

The following main roads/highways traverse the Delta:

- Interstate 5 – runs north-south on the eastern side of the Delta
- Interstate 205 – runs east-west on the southern side of the Delta
- State Highway 160 – runs north-south along the Sacramento River from Freeport to Oakley
- State Highway 12 - traverses east-west through the middle of the Delta from Fairfield through Rio Vista to Lodi
- State Highway 4 – runs east-west from Interstate 5 to Oakley
- County Roads J4 and J11 – are in the central and southern parts of the Delta, respectively

Kinder Morgan Petroleum Products Pipeline (Figure 5-5)

The Kinder Morgan pipeline traverses the Delta from east to west, from Stockton to west of Veale Tract, a distance of about 27 miles. Information provided by DWR indicates that the Kinder Morgan pipeline is a buried steel 10-inch diameter pipeline.

Mokelumne Aqueduct – Raw Water from the Sierra (Figure 5-6)

The Mokelumne Aqueduct consists of three pipelines (aqueducts) along the route where it crosses the Delta. The three aqueducts are described as follows (EBMUD 1995, 1996):

- Aqueduct #1: built in 1929; 65-inch diameter
- Aqueduct #2: built in 1949; 67-inch diameter
- Aqueduct #3: built in 1963; 87-inch diameter

Within the Delta, the aqueduct has both buried and elevated sections as follows (EBMUD 1995, 1996):

- Stockton to Whiskey Slough (Holt) – buried section (about 8½ miles). The depth of burial in trenches is about 5 feet; at the sloughs the burial depth is 15 to 20 feet.
- Whiskey Slough (Holt) to Indian Slough (Bixler) (just west of Palm-Orwood Tract) – elevated section, except at the crossings at Middle River and Old River (about 9½ miles). The elevated section is supported on steel bents at 60-foot intervals. Each bent is supported by at least four concrete batter piles.
- West of Bixler – buried section (about 18 miles). About 12 miles of the aqueduct, west of Veale Tract, is close to the legal Delta boundary.
- River crossings – River crossings are at San Joaquin, Middle River, and Old River. At the river crossings, the aqueducts are buried in trenches and backfilled with rockfill. Aqueducts #1 and #2 are on piles that are founded in dense sand at Middle and Old Rivers. Aqueduct #3 is buried 30 feet below slough bottoms.

Aqueduct #3 was seismically upgraded so that it could be returned to service within 6 months after the "Maximum Earthquake" on the Coast Range Central Valley fault (EBMUD 1995, 1996). EBMUD has very limited local storage or supplemental local supply sources. Thus an aqueduct outage would be of major concern.

Railroads (Figure 5-7)

The Burlington Northern Santa Fe railroad traverses the Delta and Suisun Marsh from east to west, from Stockton to Interstate 780. The other railroads are generally around the periphery of the Delta.

The railroad tracks are mainly supported on embankments in the Delta. On the north side of Woodward Island, the railroad is on a trestle bridge that is supported on piles. No direct information about the depth of piles was available. However, based on experience with similar trestle bridges, the depth of piles is expected to be 70 to 80 feet.

The railroad traverses between Upper and Lower Jones tracts on an embankment fill, except for a bridge over a passage between the two islands. The west abutment of the bridge was scoured during the June 2004 Jones Tract levee failure (URS 2005).

5.5.2 Point Assets

The locations of point assets are shown on Figure 5-8 (solid waste facilities and sewage treatment plants), Figure 5-9 (businesses), and Figure 5-10 (miscellaneous data, e.g., ports, airports, and health care facilities).

Residences

Residences are scattered throughout the Delta; however, not all islands are populated or have residential structures. Urban areas (with concentrations of residences) within or near the Delta include Rio Vista, West Sacramento (and the "Pocket Area"), Elk Grove, Clarksburg, Hood, Courtland, Walnut Grove, Isleton, Oakley, Brentwood, Stockton, Lathrop, Manteca, and Tracy.

The data pertaining to residential structures were generated by HAZUS (FEMA 2006). Several different types of residential structures include single-family housing (one to three stories), mobile homes, duplexes, triplets/quads (one to five stories), apartment buildings, motels/hotels, institutional dormitories, and residences.

Commercial Buildings

Commercial buildings are scattered throughout many Delta islands (Figure 5-9) and include low, mid-size, and high-rise structures. HAZUS (FEMA 2006) has defined the following types of commercial structures in the Delta: agricultural structures, retail and wholesale trade, repair services, professional/technical, services, banks, hospitals, medical offices/clinics, and entertainment and recreation.

Industrial Facilities

Industrial buildings are also scattered throughout the Delta. HAZUS data shows that industrial structures in the Delta include heavy and light industry, high technology industry, construction industry, metals and mineral processing, and food and drug chemicals.

Bridges

Three types of bridges lie within the Delta: highway bridges, railroad bridges, and nonhighway bridges.

Oil/Gas and Water Wells

Oil, gas, and water wells scattered throughout the Delta are shown on Figure 5-5.

Natural Gas/Field Storage

PG&E has a natural gas field on McDonald Island. The gas field equipment is on platforms 30 feet above ground level.

Ports

These assets include the ports of Sacramento and Stockton and ports along the west side of the Delta.

Water System Assets

Water system assets within, or close to, the Delta include pumping plants, gates, and intakes owned by DWR, Contra Costa Water District, and Bureau of Reclamation. The pumping plants are shown on Figure 5-6 and include the following:

- DWR pumping plants: Harvey O. Banks (California Aqueduct), South Bay (South Bay Aqueduct), and Barker Slough (North Bay Aqueduct)
- Contra Costa Water District pumping plants: Old River, Mallard Slough, Rock Slough Intake, and Pumping Plants 1 through 4
- Bureau of Reclamation's Central Valley Project: C.W. "Bill" Jones Pumping (formerly Tracy Pumping Plant) (Delta-Mendota Canal).

Power Plants

Power plants in the Pittsburg–Antioch area are within the Delta study area; however, these assets are not protected by levees.

5.5.3 Asset Value of Infrastructure

The asset value (defined herein as replacement cost) of infrastructure was considered for two levee failure scenarios. For the Delta Risk Management Strategy (DRMS) project, the term "infrastructure" is used to designate all structures and buildings, and their contents. The first looked at the assets that could be flooded if all levees were to fail with sea level at MHHW; the average elevation of the highest of the two tides each day over a 19-year period). The second looked at the assets that could be flooded if all the levees were to fail at the 100-year flood level. (The estimate of the boundary of the 100-year floodplain was developed from Federal Emergency Management Agency Flood Insurance Rate Maps, which are currently being updated.) The current (2005) estimated value of assets (including building contents) for these two scenarios follows:

- MHHW: $6.7 billion
- 100-year flood: $56.3 billion

The total value of assets for the 100-year flood significantly exceeds the value of the assets that are below the MHHW level. The 100-year flood event has the potential to inundate major urban areas, such as in West Sacramento, the Pocket Area of Sacramento, and Stockton, that have large inventories of infrastructure assets. However, the MHHW limits do not extend to these large urban areas. Small towns and rural/agricultural areas mainly fall within the MHHW limits. Figure 5-11 shows the areas included in the MHHW and the 100-year limit designations.

Besides inundation damage, infrastructure assets are subject to damage due to scour at levee breach locations. Assets that are within the scour zones adjacent to a levee breach are assumed to be destroyed (i.e., scour holes could occur anywhere within the island perimeter and a location is to be specified for each breach in any given levee breach scenario so that scour damage can be assessed). Based on historical data, the scour zones were defined to be 2,000 feet long (perpendicular to the island perimeter/levee) (see Section 12). Scour limits are shown on Figure 5-12. The location of the scour can be a significant part of loss-of-use and repair cost estimates, depending on the location of a specific breach. In such a case the scour limit is the edge of the scour zone (i.e., 2000 feet landward of the levee [perpendicular to the island perimeter/levee], 500 feet wide [parallel to the island perimeter/levee], and 50 feet deep). These dimensions are based on historical scour events.

Because some asset types lack attribute information, it was not always possible to estimate asset costs from the geographic information system (GIS) data (geographic information system files) developed as part of DRMS drawing on several sources. This information was used to estimate the Delta infrastructure losses in each specific levee breach scenario in the risk analysis. The GIS data usually include attributes or characteristics of the infrastructure assets. Attributes include pipeline diameters, number of stories of buildings, and number of tanks in a tank farm. These attributes are needed to develop replacement cost estimates for the various assets that may be damaged by flooding or scour. The initial GIS database and its augmentation with data from other sources is described in more detail in the Impact to Infrastructure TM (URS/JBA 2007f).

In cases where some of this attribute data are missing, available information may be insufficient to evaluate reliable replacement and repair costs. Assumptions had to be made so that damage losses could be estimated. As a result of this limitation, the replacement and repair costs may be under-represented. Further characterization of the Delta infrastructure assets would reduce the uncertainty in the damage estimates. In addition, because of the lack of information on repair times (due to the absence of historical experience), especially for multi-island failures, URS' staff used its best engineering judgment to estimate repair times.

Note that this compilation of infrastructure subject to levee breach damage does not address the issue of public safety and potential injuries or death. That is a different topic.

5.6 GEOMORPHOLOGY, SUBSIDENCE, AND TOPOGRAPHY

The freshwater tidal marshes of the historic Delta were created after the last ice age as wetland vegetation growth kept pace with gradually rising sea level by capturing sediment and forming peat soils. Over the last 5,000 years this phenomenon allowed the marsh to expand vertically and laterally into the Central Valley, eventually creating about 380,000 acres of tidally influenced marsh and channels, the largest freshwater tidal marsh on the west coast of North America (Figure 5-13). Because this marsh was a freshwater system, marsh vegetation could colonize below low tide level, vegetating emergent mudflats and precluding the formation of large wind-wave-generated expanses of open water that occur in the saltwater-influenced portion of the estuary.

This scenario meant that in the historic Delta, the morphology of the marshes and channels maintained a dynamic equilibrium with the main physical processes; the tides, floods, the transport of sediment, and sea-level rise that shaped it. It also meant that the tidal prism, the volume of the tides that flowed in and out of the Delta on a tidal cycle, was quite limited for such an extensive estuarine system, and was determined almost entirely by the volume of water in the sinuous tidal channels that drained the marshes. Sediments discharged into the Delta during large floods on the Sacramento or San Joaquin Rivers would either be conveyed through the Delta to Suisun Bay or captured within the tidal marsh.

Over the last 150 years, the natural landscape elements of the Delta have been transformed by human activities. The large tule marsh of the Delta has been converted by levee building into a highly dissected region of channels and leveed islands used for agriculture (Simenstad et al. 2000). Only a few examples of relatively pristine tidal marsh still exist, such as Browns Island and on narrow bands of emergent vegetation located between the channels and levees. Even though marshes grow on the exterior of levees in the Delta, and Suisun Marsh has managed marshes, creation of the levees removed the marsh/upland transition zone, an area of unique biodiversity. These marshes amount to less than 2 percent of the historic marsh. Much of the natural riparian vegetation bordering distributary channels has also been lost. In general, levees were constructed either along firmer ground on the natural levees of distributary channels or along the edge of the larger natural tidal channels.

As the tidal marsh was reclaimed, the natural tidal and distributary channel system was extensively modified to provide for navigable access to farms and by excavation to build up levees. The main Delta channels have been widened, dredged, and straightened to allow for passage of ships. Dredging of the Sacramento River Deep Water Ship Channel makes it navigable for ocean-going ships as far inland as Sacramento. Cache Slough is also dredged as it forms part of this Ship Channel. Along the San Joaquin River, the dredged Stockton Deep Water Ship Channel makes the lower reach of the river navigable for ocean shipping as far inland as Stockton. At Stockton, an abrupt change occurs in channel geometry from a deep channel downstream to a shallow river channel upstream.

Land subsidence has placed most of the Delta land below sea level. Subsidence varies with location, but rates of 0.5 to 1.5 inches of soil loss per year are common in the Delta. This historical subsidence has left multiple islands with average land elevations as much as 15 feet or more below MSL. Several islands have areas as much as 25 feet below sea level. Subsidence of the peat soils behind the levees has created a large artificial empty space below high tide level, or potential accommodation space. This accommodation space of over 2 billion cubic meters below sea level can be filled by flood waters in the event of levee failures (Mount and Twiss 2005).

Over the last 80 years several islands, including Franks Tract and Big Break, have been abandoned after the levees failed. Because the abandoned island floors were subsided below the limit of colonization of marsh vegetation, large expanses of open water were formed. These large flooded islands allowed for long wind fetches and high levels of wind-wave action that resuspend sediments deposited during flood events. These human-created large expanses of open water have been a major contributor to an approximate doubling of the tidal prism of the Delta even though approximately 98 percent of the historic tidal marsh has been converted to agricultural land. Alluvial sediment deposition in the Delta is currently estimated to be 1.8 million tons per year.

In the Suisun Marsh, subsidence is also occurring, but less information is available about rates and processes affecting rates. The land use for much of the Suisun Marsh is managed wetlands, which has reduced the subsidence rate compared with the Delta. Permanently flooded areas may have reversed subsidence by accumulating vegetation and sediment.

The topography of the area is relatively flat. Much of the area lies below the MHHW elevation. Figure 5-14 shows the land surface elevations in the Delta and Suisun Marsh.

Table 5-1 Listed Species in the Delta and Suisun Marsh

Species name	Common Name	No. in Delta & Suisun Marsh	Status			
			Federal	CA	CDFG	CNPS
Acipenser medirostris	Green Sturgeon southern Distinct Population Segment	NA	T	SC	--	--
Agelaius tricolor	Tricolored blackbird	7	--	--	SC	--
Ambystoma californiense	California tiger salamander	13	T	--	SC	--
Anniella pulchra pulchra	Silvery legless lizard	3	--	--	SC	--
Archoplites interruptus	Sacramento perch	2	--	--	SC	--
Arctostaphylos auriculata	Mt. Diablo manzanita	1	--	--	--	1B.3
Asio flammeus	short-eared owl	1	--	--	SC	--
Aster lentus	Suisun Marsh aster	129	--	--	--	1B.2
Astragalus tener var. *ferrisiae*	Ferris' milk-vetch	3	--	--	--	1B.1
Astragalus tener var. *tener*	alkali milk-vetch	12	--	--	--	1B.2
Athene cunicularia	burrowing owl	104	--	--	SC	--
Atriplex cordulata	heartscale	1	--	--	--	1B.2
Atriplex depressa	brittlescale	2	--	--	--	1B.2
Atriplex joaquiniana	San Joaquin spearscale	9	--	--	--	1B.2
Atriplex persistens	vernal pool smallscale	1	--	--	--	1B.2
Blepharizonia plumosa	big tarplant	4	--	--	--	1B.1
Branchinecta conservatio	Conservancy fairy shrimp	4	E	--	--	--
Branchinecta lynchi	vernal pool fairy shrimp	10	T	--	--	--
Buteo regalis	ferruginous hawk	1	--	--	SC	--
Buteo swainsoni	Swainson's hawk	294	--	T	--	--
California macrophyllum	round-leaved filaree	2	--	--	--	1B.1
Carex comosa	bristly sedge	3	--	--	--	2.1
Carex vulpinoidea	fox sedge	1	--	--	--	2.2
Centromadia parryi ssp. *congdonii*	Congdon's tarplant	1	--	--	--	1B.2
Centromadia parryi ssp. *parryi*	pappose tarplant	3	--	--	--	1B.2
Circus cyaneus	northern harrier	3	--	--	SC	--
Cirsium crassicaule	slough thistle	2	--	--	--	1B.1
Cirsium hydrophilum var. *hydrophilum*	Suisun thistle	3	E	--	--	1B.1
Coccyzus americanus occidentalis	western yellow-billed cuckoo	2	C	E	--	--
Cordylanthus mollis ssp. *mollis*	soft bird's-beak	17	E	R	--	1B.2
Cryptantha hooveri	Hoover's cryptantha	1	--	--	--	1A

Table 5-1 Listed Species in the Delta and Suisun Marsh

Species name	Common Name	No. in Delta & Suisun Marsh	Status			
			Federal	CA	CDFG	CNPS
Delphinium recurvatum	recurved larkspur	4	--	--	--	1B.2
Desmocerus californicus dimorphus	valley elderberry longhorn beetle	3	T	--	--	--
Downingia pusilla	dwarf downingia	7	--	--	--	2.2
Emys (=Clemmys) marmorata	western pond turtle	45	--	--	SC	--
Emys (=Clemmys) marmorata marmorata	northwestern pond turtle	10	--	--	SC	--
Eremophila alpestris actia	California horned lark	1	--	--	SC	--
Eriogonum truncatum	Mt. Diablo buckwheat	2	--	--	--	1B.1
Eryngium racemosum	Delta button-celery	2	--	E	--	1B.1
Erysimum capitatum ssp. *angustatum*	Contra Costa wallflower	3	E	E	--	1B.1
Eschscholzia rhombipetala	diamond-petaled California poppy	1	--	--	--	1B.1
Fritillaria liliacea	fragrant fritillary	3	--	--	--	1B.2
Geothlypis trichas sinuosa	saltmarsh common yellowthroat	22	--	--	SC	--
Gratiola heterosepala	Boggs Lake hedge-hyssop	1	--	E	--	1B.2
Hesperolinon breweri	Brewer’s western flax	1	--	--	--	1B.2
Hibiscus lasiocarpus	rose-mallow	80	--	--	--	2.2
Hypomesus transpacificus	delta smelt	3	T	T	--	--
Isocoma arguta	Carquinez goldenbush	2	--	--	--	1B.1
Juglans hindsii	Northern California black walnut	1	--	--	--	1B.1
Lanius ludovicianus	loggerhead shrike	2	--	--	SC	--
Lasthenia conjugens	Contra Costa goldfields	1	E	--	--	1B.1
Laterallus jamaicensis coturniculus	California black rail	30	--	T	--	--
Lathyrus jepsonii var. *jepsonii*	Delta tule pea	116	--	--	--	1B.2
Legenere limosa	legenere	5	--	--	--	1B.1
Lepidium latipes var. *heckardii*	Heckard’s pepper-grass	3	--	--	--	1B.2
Lepidurus packardi	vernal pool tadpole shrimp	8	E	--	--	--
Lilaeopsis masonii	Mason’s lilaeopsis	139	--	R	--	1B.1
Limosella subulata	Delta mudwort	42	--	--	--	2.1
Madia radiata	showy madia	1	--	--	--	1B.1
Melospiza melodia maxillaris	Suisun song sparrow	33	--	--	SC	--
Navarretia leucocephala ssp. *bakeri*	Baker’s navarretia	3	--	--	--	1B.1

Table 5-1 Listed Species in the Delta and Suisun Marsh

Species name	Common Name	No. in Delta & Suisun Marsh	Status			
			Federal	CA	CDFG	CNPS
Oenothera deltoides ssp. *howellii*	Antioch Dunes evening-primrose	9	E	E	--	1B.1
Oncorhynchus mykiss	Central Valley steelhead	NA	T	--	--	--
Oncorhynchus tshawytscha	Sacramento River winter-run Chinook salmon	NA	E	E	--	--
Oncorhynchus tshawytscha	Central Valley spring-run Chinook salmon	NA	T	T	--	--
Phalacrocorax auritus	double-crested cormorant	3	--	--	SC	--
Plagiobothrys hystriculus	bearded popcorn-flower	2	--	--	--	1B.1
Pogonichthys macrolepidotus	Sacramento splittail	5	--	--	SC	--
Potamogeton zosteriformis	eel-grass pondweed	1	--	--	--	2.2
Rallus longirostris obsoletus	California clapper rail	20	E	E	--	--
Rana aurora draytonii	California red-legged frog	8	T	--	SC	--
Reithrodontomys raviventris	salt-marsh harvest mouse	48	E	E	--	--
Riparia riparia	bank swallow	1	--	T	--	--
Sagittaria sanfordii	Sanford's arrowhead	3	--	--	--	1B.2
Scutellaria galericulata	marsh skullcap	3	--	--	--	2.2
Scutellaria lateriflora	blue skullcap	2	--	--	--	2.2
Sorex ornatus sinuosus	Suisun shrew	7	--	--	SC	--
Spirinchus thaleichtys	Longfin smelt	NA	--	SC	--	--
Sterna antillarum browni	California least tern	3	E	E	--	--
Sylvilagus bachmani riparius	riparian brush rabbit	2	E	E	--	--
Taxidea taxus	American badger	3	--	--	SC	--
Thamnophis gigas	giant garter snake	15	T	T	--	--
Trichocoronis wrightii var. *wrightii*	Wright's trichocoronis	1	--	--	--	2.1
Tropidocarpum capparideum	caper-fruited tropidocarpum	6	--	--	--	1B.1
Tuctoria mucronata	Crampton's tuctoria or Solano grass	1	E	E	--	1B.1
Vulpes macrotis mutica	San Joaquin kit fox	8	E	T	--	--

Legend: E = Endangered; SC= Species of Concern; R = Rare; T = Threatened; 1B = listed by the California Native Plant Society as rare, threatened or endangered in California and elsewhere, based on statewide review by CNPS botanical experts and network of field observers; 2 listed by CMPS as rare/threatened /endangered in California, but more abundant elsewhere; .1 - Seriously endangered in California (over 80% of occurrences threatened / high degree and immediacy of threat); .2 – Fairly endangered in California (20 - 80% occurrences threatened); .3 – Not very endangered in California (<20% of occurrences threatened or no current threats known)

Table 5-2
Delta Protected Area Business Profile: 2005 Output and Employment by Sector

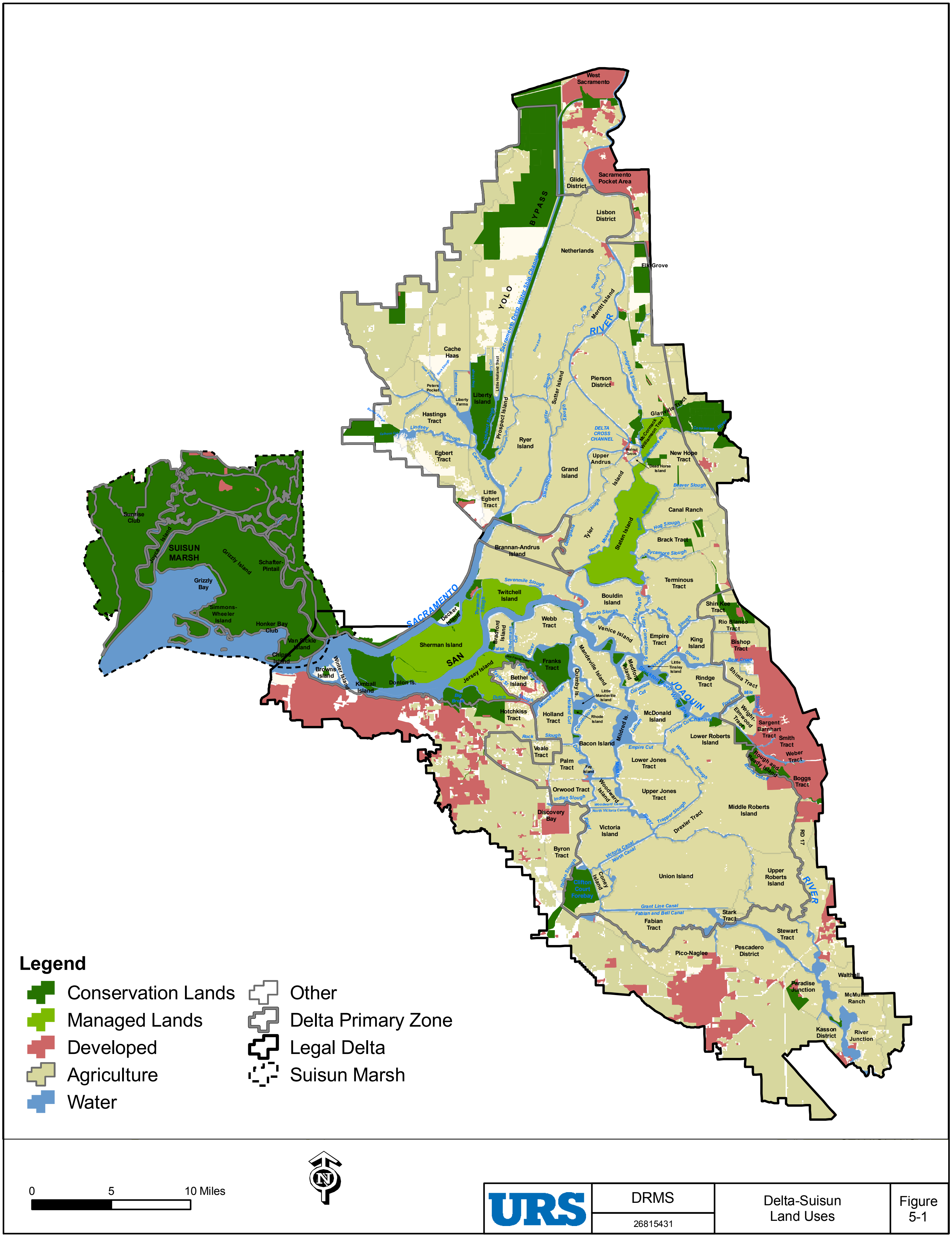
Sector	NAICS[1]	Annual Billion $ Sales	Number of Employees
Agriculture	11299013	$0.21	1,132
Fishing	11421004	$0.01	25
Agricultural support	11531005	$0.08	827
Oil & gas	21111102	$0.01	2
Drilling	21311209	$0.03	135
Power generation	22112202	$0.11	39
Natural gas distribution	22121001	$0.00	4
Water, sewer	22131003	$0.02	65
Construction	23899096	$1.70	7,129
Manufacturing	33999940	$3.37	9,567
Wholesale & distribution	42512086	$9.14	12,021
Motor vehicles & parts	44132001	$0.93	2,034
Retail	45439017	$2.91	15,427
Transportation warehousing and storage	48899102	$0.62	4,918
Publishing, telecommunications, IS	51919020	$0.70	6,225
Financial, insurance, real estate, rental	53249013	$2.13	8,200
Services	56299806	$3.81	24,238
School & education	61171010	$0.09	9,611
Medical, day care, social assistance	62441006	$6.55	32,363
Entertainment	71399050	$0.27	5,629
Accommodations	72131006	$0.16	2,556
Restaurants, etc.	72241006	$0.53	11,173
Auto services, repair and maintenance, personal services	81299041	$0.47	5,240
Religious, civic	81399005	$0.13	6,350
Other	99999000	$0.03	39,202
TOTAL		$34.01	204,112

[1] NAICS number of the last business in that named group

Table 5-3
2005 Economic Data for California, the Greater Bay Area, and Delta Counties

	California	**Greater Bay Area (GBA)**	**Three Delta Counties not in GBA**	**GBA and Delta Counties**	**Six Delta Counties**
Population (M)	37	7.2	2.2	9.4	5.1
Personal Income (B$)	1,350	363	68	431	237
Per Capita Personal Inc. ($)	37,462	50,836	31,119	46,187	55,284
Employment (M)	20.0	4.5	1.2	5.6	2.9

Source: U.S. Dept. of Commerce, BEA 2008.



0 5 10 Miles

URS

DRMS

26815431

Delta-Suisun Land Uses

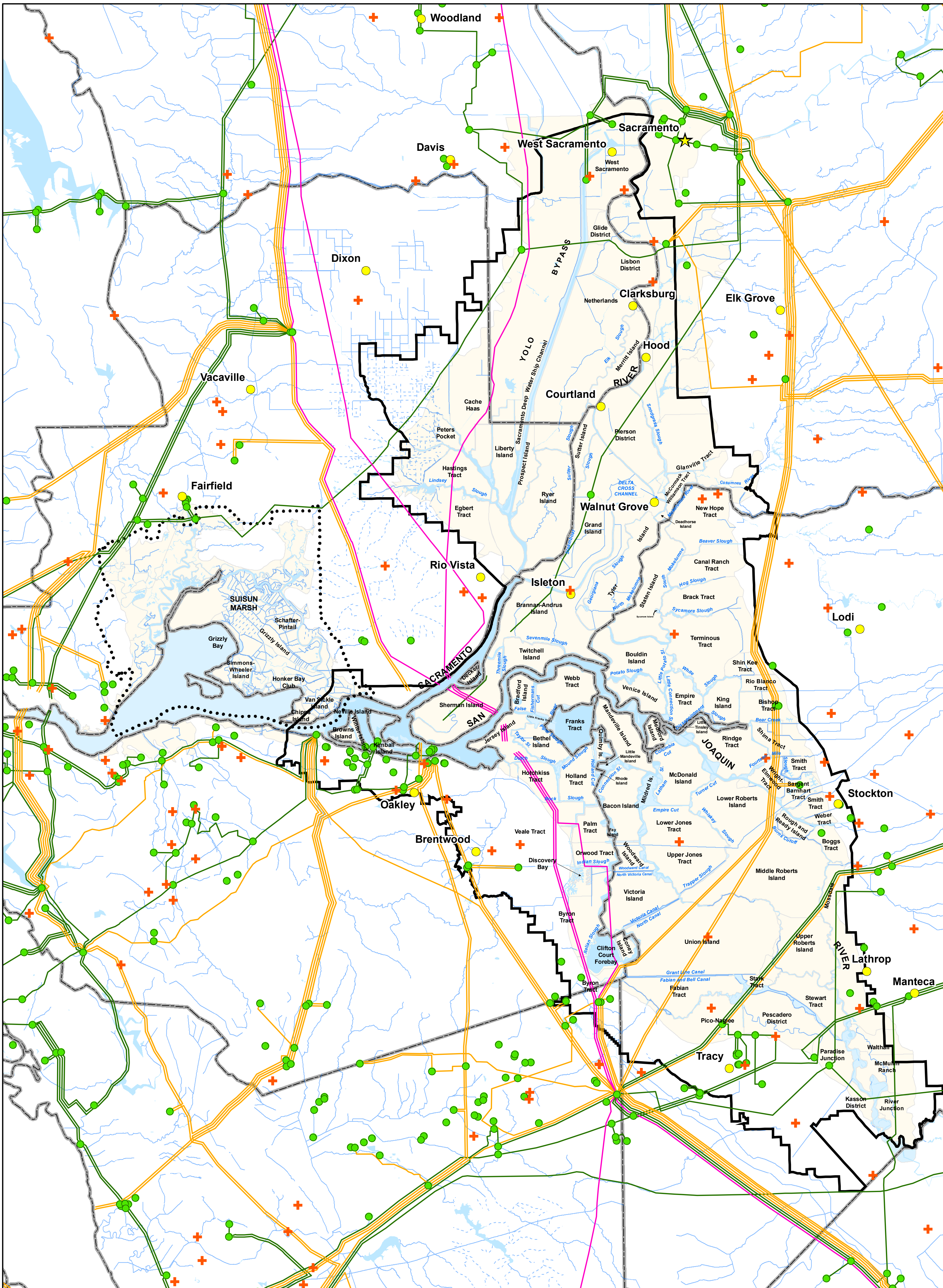
Figure 5-1

URS Corporation P:\GIS\GIS_Project_Files\MXD\Analysis\Landuse\landuse_041807.mxd Date: 4/18/2007 4:09:02 PM Name: smlewis0

Figure 5-2

PG&E Natural Gas Pipelines

[Proprietary information. Publication not Permitted.]



Legend

- Substations
- US Cell Towers

Transmission Lines

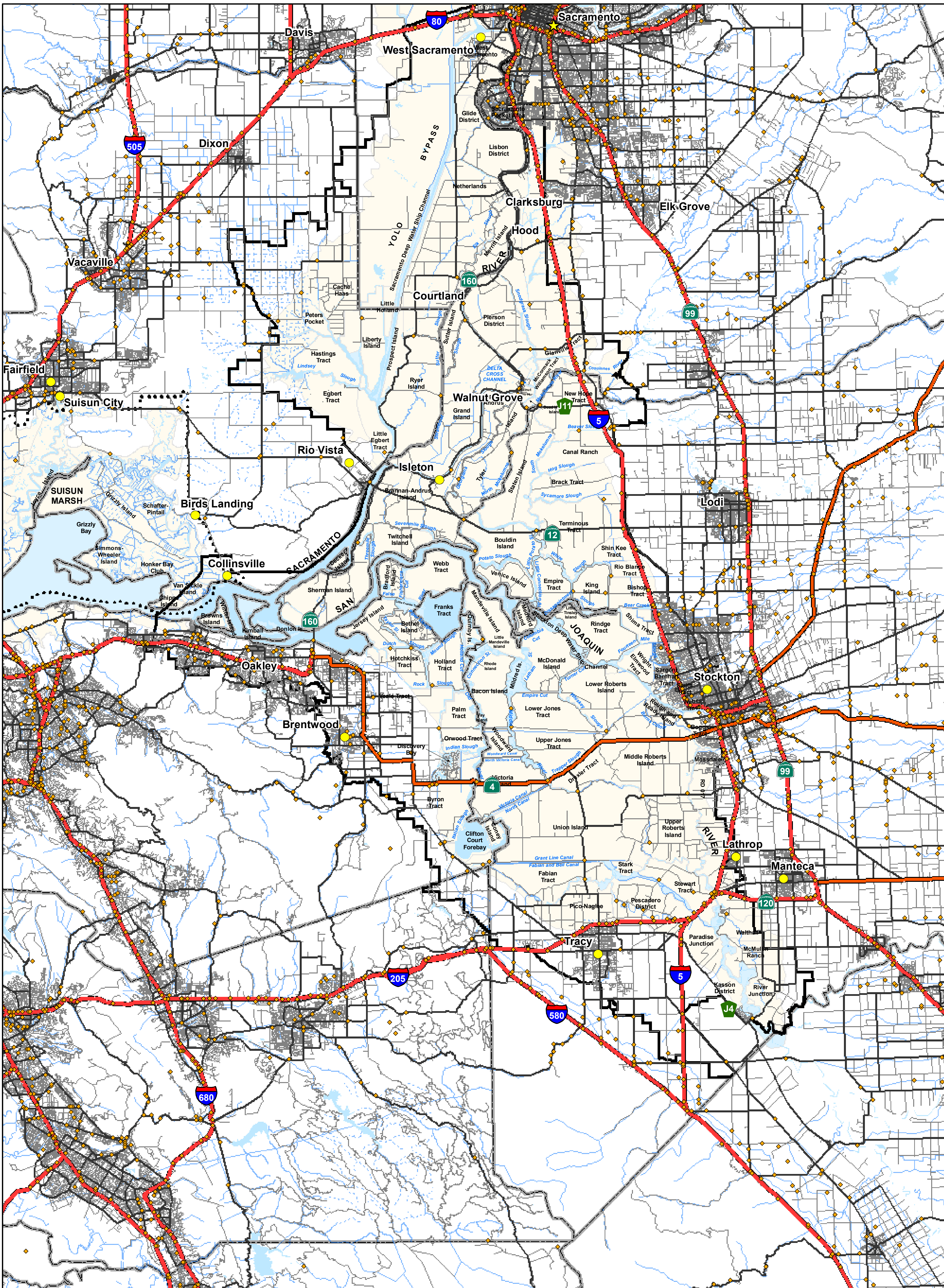
- 230kV - 344kV
- 500kV - 734kV
- Below 230kV

- Intermittent canal, ditch, aqueduct, stream, river, or wash
- Perennial canal, ditch, or aqueduct; stream, river; reservoir
- CA Water
- CA Counties
- Legal Delta
- Suisun Marsh

0 5 10 Miles

URS	DRMS 26815431	Transmission Lines, Substations & Cell Towers	Figure 5-3

URS Corporation P:\GIS\GIS_Project_Files\MXD\Current Working Documents\Infrastructure\tech_memo_R1_010507\2-3 Transmission Lines, Substations & Cell Towers.mxd Date: 1/5/2007 9:10:23 AM Name: smlewis0



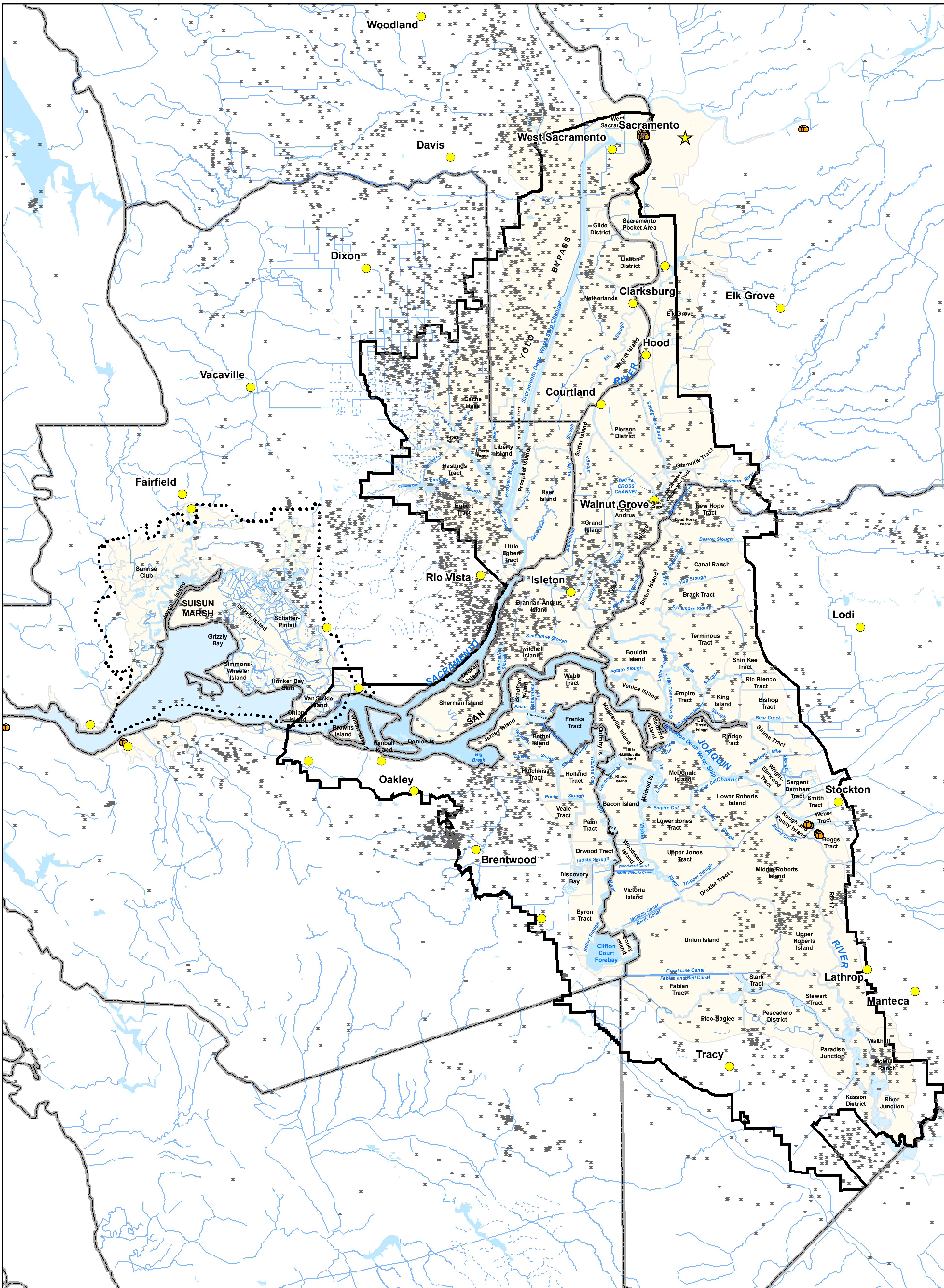
Legend

- Highway
- Major Road
- Local Road
- Bridges
- Intermittent canal, ditch, aqueduct, stream, river, or wash
- Perennial canal, ditch, or aqueduct; stream, river; reservoir
- CA Water
- CA Counties
- Legal Delta
- Suisun Marsh

0 5 10 Miles

URS	DRMS 26815431	Highways and Roads	Figure 5-4

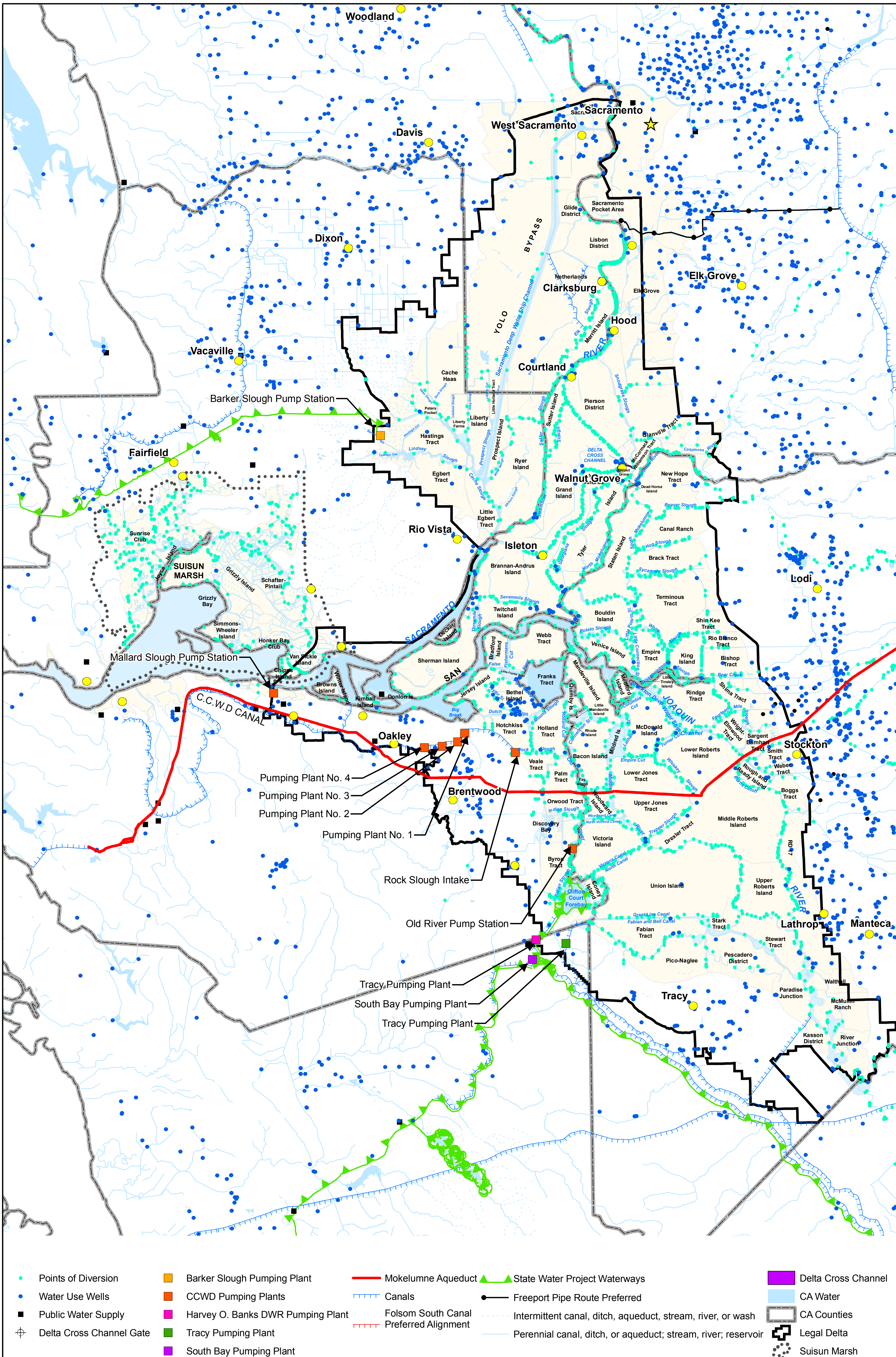
URS Corporation P:\GIS\GIS_Project_Files\MXD\Current Working Documents\Infrastructure\tech_memo\2-7 Highways and Roads.mxd Date: 1/2/2007 11:02:54 AM Name: smlewis0



Tank Farm
Gas and Oil Well
Gas and Oil Production Field
Intermittent canal, ditch, aqueduct, stream, river, or wash
Perennial canal, ditch, or aqueduct; stream, river; reservoir
CA Water
CA Counties
Legal Delta
Suisun Marsh

0 5 10 Miles

DRMS	Oil & Gas	Figure 5-5
26815431		



URS

DRMS

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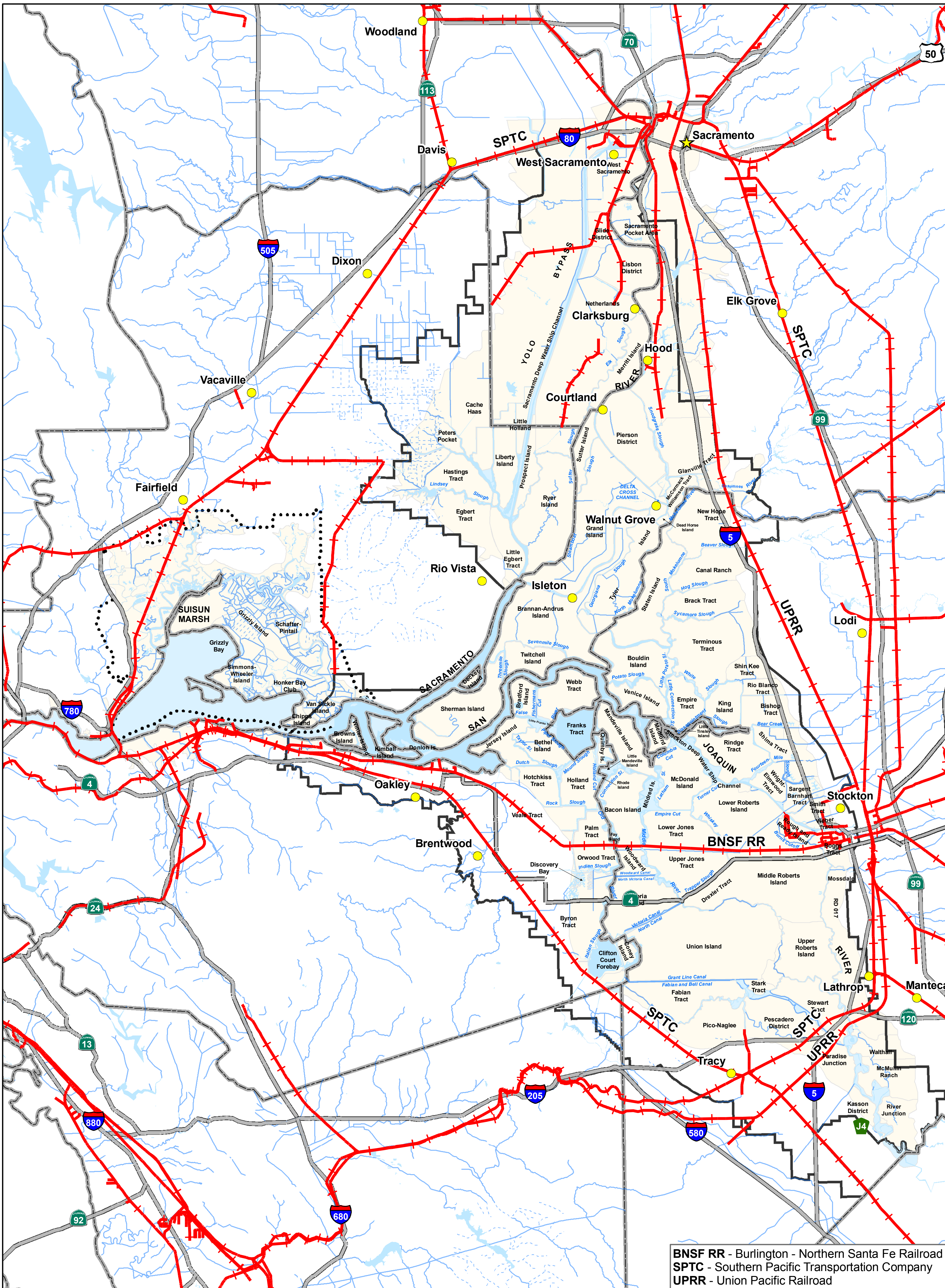
Water Wells, Canals & Mokelumne Aqueduct

Figure 5-6

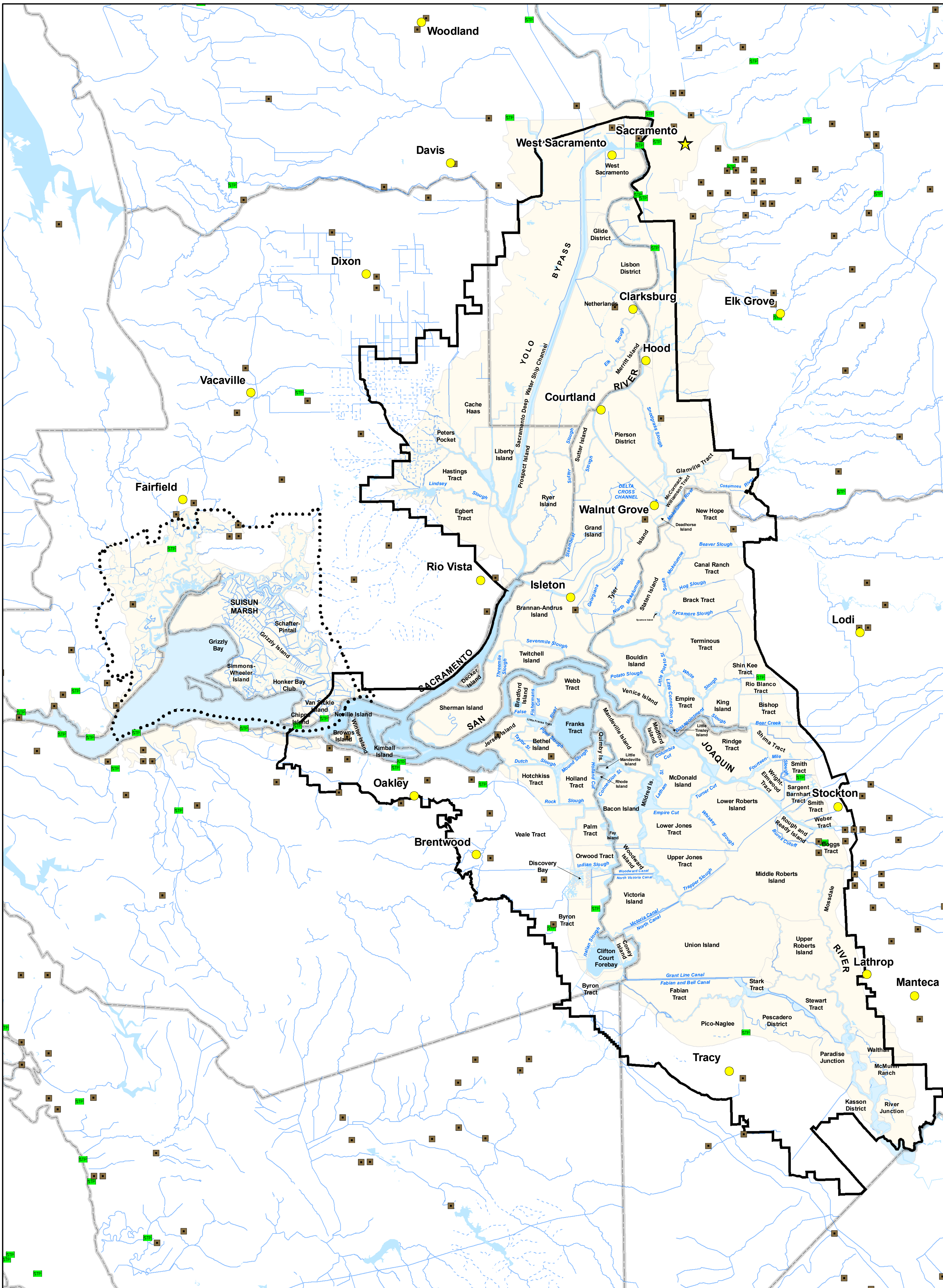


Legend

- Railroads
- Highway
- Railroad Nodes
- Intermodal Terminal Facilities
- Intermittent canal, ditch, aqueduct, stream, river, or wash
- Perennial canal, ditch, or aqueduct; stream, river; reservoir
- CA Water
- CA Counties
- Legal Delta
- Suisun Marsh

0 5 10 Miles

DRMS	Railroads	Figure 5-7
26815431		



Legend

Solid Waste Facilities	Intermittent canal, ditch, aqueduct, stream, river, or wash	CA Counties
Sewage Treatment Plant	Perennial canal, ditch, or aqueduct; stream, river; reservoir	Legal Delta
	CA Water	Suisun Marsh

0 5 10 Miles

URS

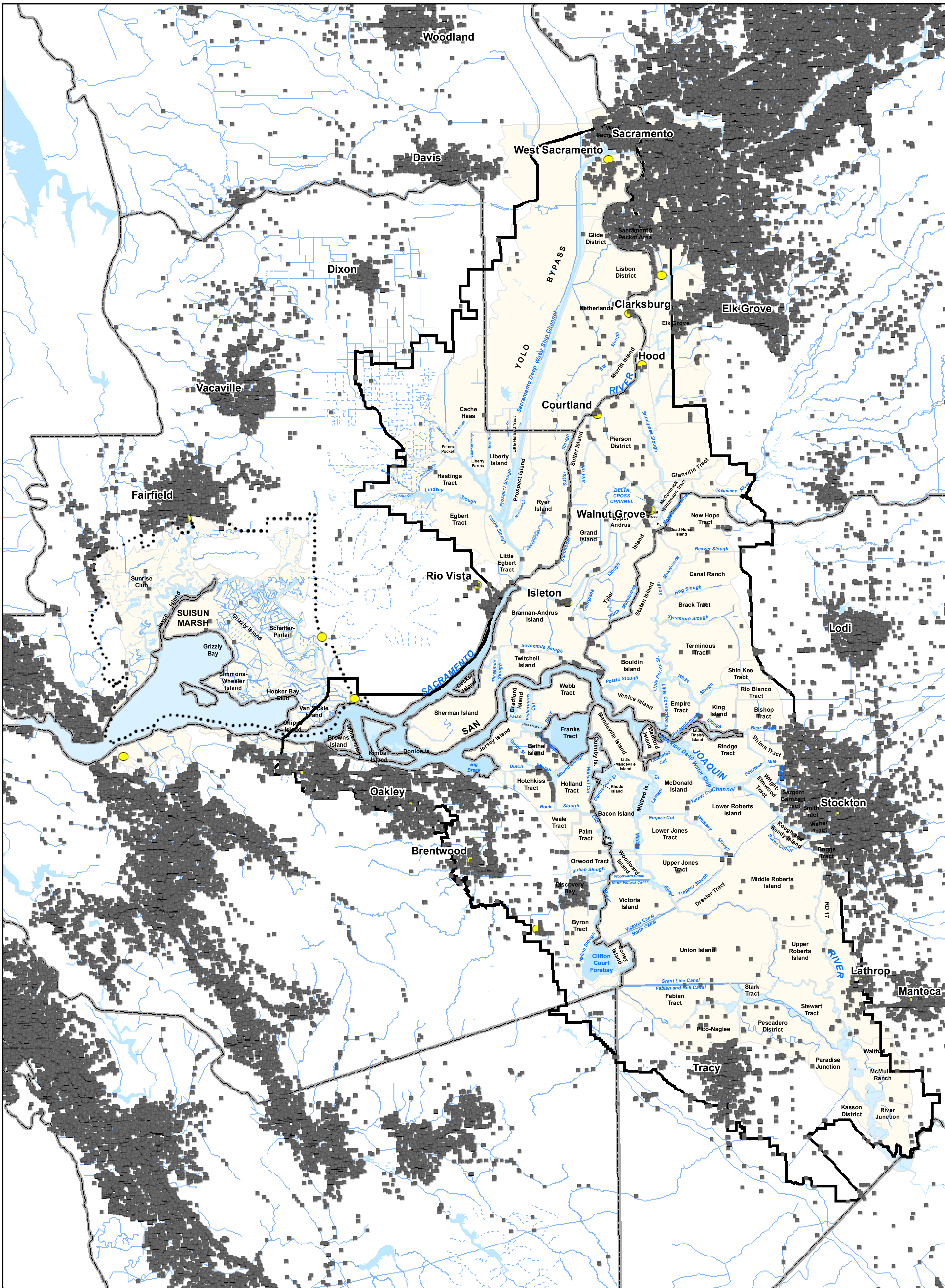
DRMS

26815431

Solid Waste Facilities & Sewage Treatment Plants

Figure 5-8

URS Corporation P:\GIS\GIS_Project_Files\MXD\Current Working Documents\Infrastructure\tech_memo_R1_010507\2-8 Solid Waste Facilities & Sewage Treatment Plants.mxd Date: 1/5/2007 9:54:38 AM Name: smlewis0



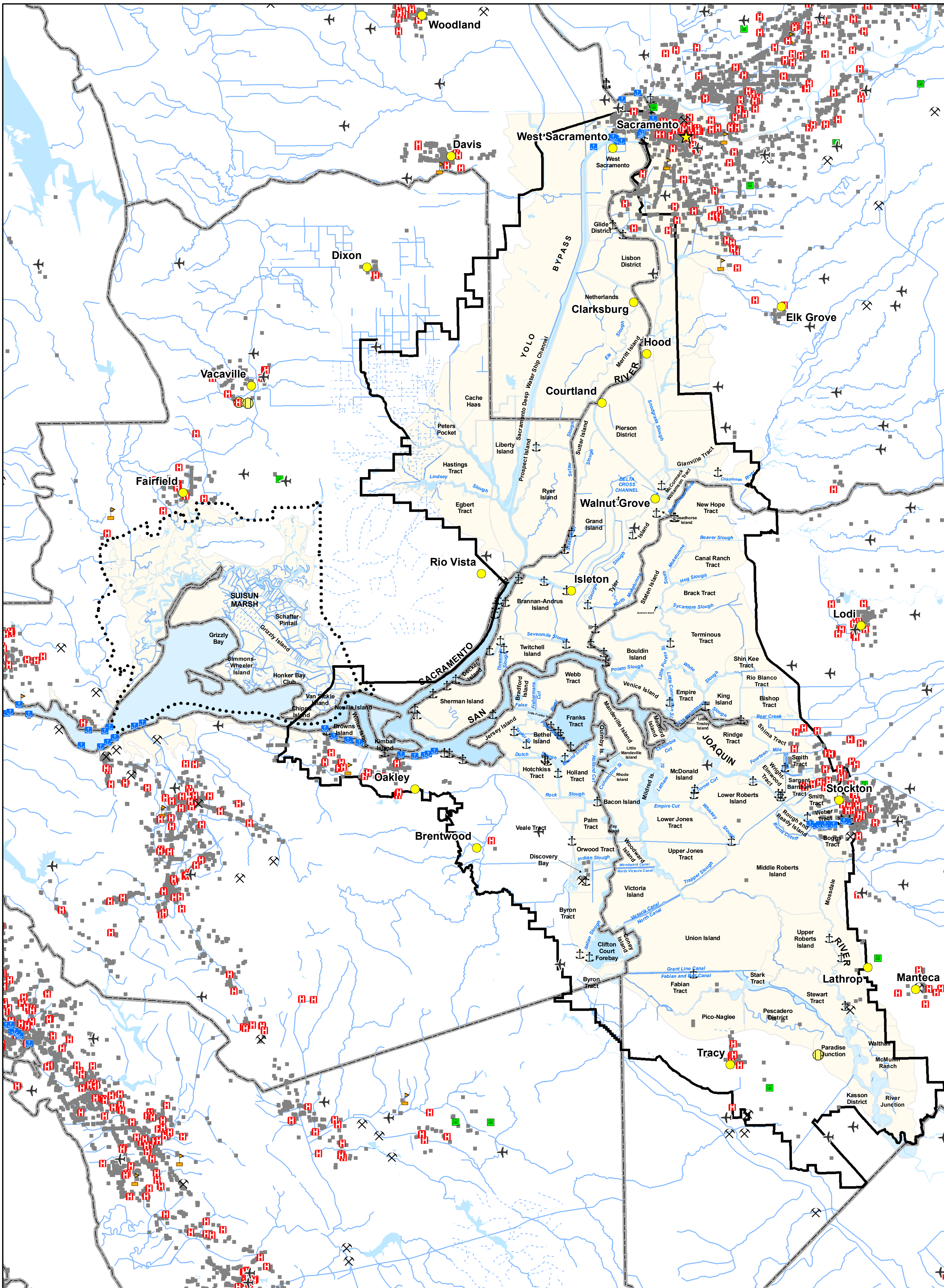
Legend

- Business
- Intermittent canal, ditch, aqueduct, stream, river, or wash
- Perennial canal, ditch, or aqueduct; stream, river; reservoir
- CA Water
- CA Counties
- Legal Delta
- Suisun Marsh

0 5 10 Miles

URS	DRMS	Businesses	Figure 5-9
	26815431		

URS Corporation P:\GIS\GIS_Project_Files\MXD\Current Working Documents\Infrastructure\tech_memo_R1_010507\2-9 Businesses.mxd Date: 1/5/2007 11:03:40 AM Name: smlewis0



Legend

Higher Education	Licensed Healthcare Facilities	Intermittent canal, ditch, aqueduct, stream, river, or wash	CA Counties
Boatlaunch	BLM Quarry and Mining Operations	Perennial canal, ditch, or aqueduct; stream, river; reservoir	Legal Delta
Prison	Airports	CA Water	Suisun Marsh
Superfund Sites	buildings		
	port		

0 5 10 Miles

N

URS

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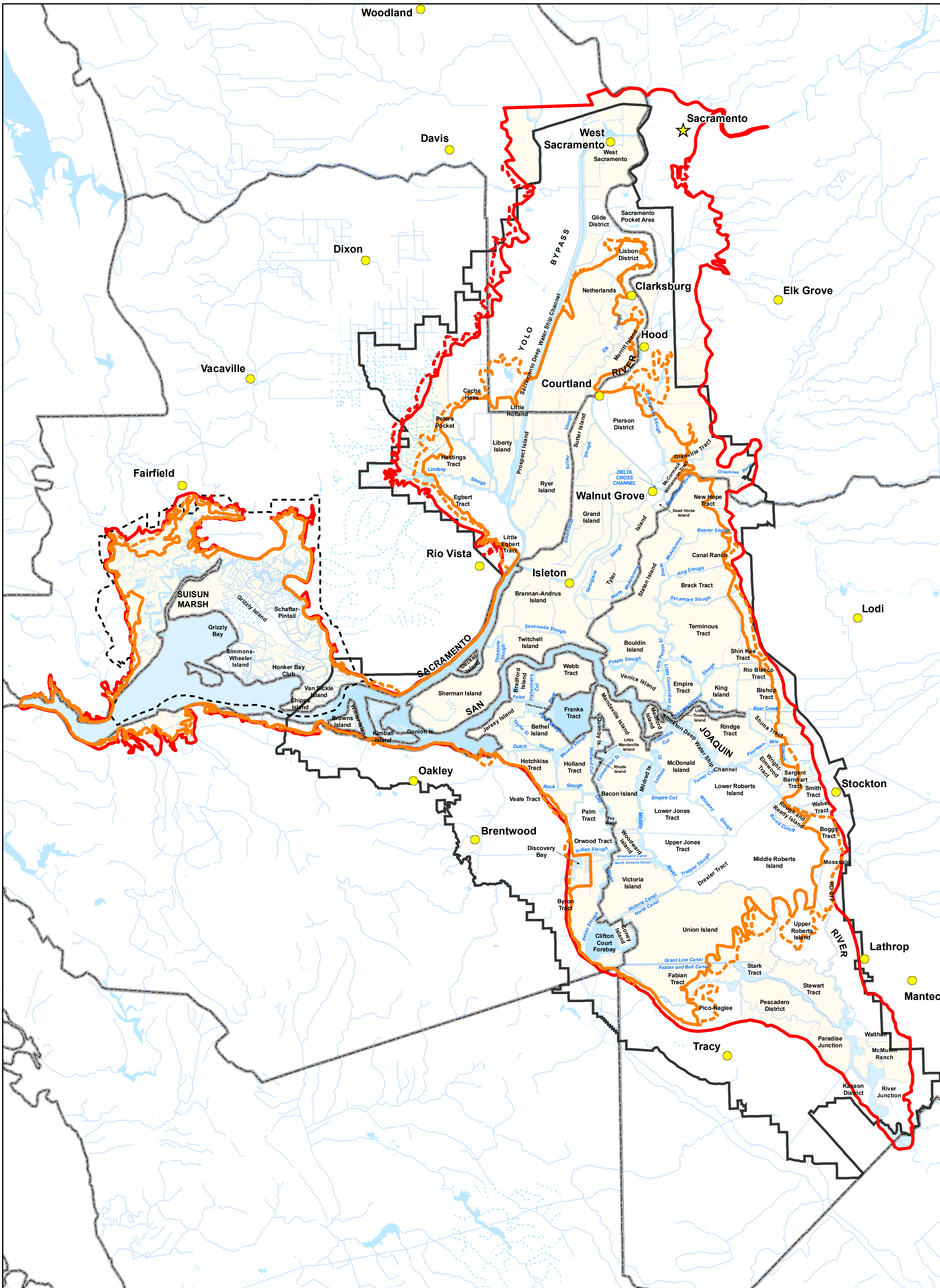
Miscellaneous Data

Figure 5-10

URS Corporation P:\GIS\GIS_Project_Files\MXD\Current Working Documents\Infrastructure\tech_memo_R1_0105072-10 Misc Data.mxd Date: 1/5/2007 11:04:53 AM Name: smlewis0



Legend

- MHHW Boundary (Current)
- MHHW (2050)
- 100-Year Floodplain (Current)
- 100-Year Floodplain (2050)
- CA Water
- Intermittent canal, ditch, aqueduct, stream, river, or wash
- Perennial canal, ditch, or aqueduct; stream, river; Reservoir
- CA Counties
- Legal Delta
- Suisun Marsh

0 5 10 Miles

N

URS

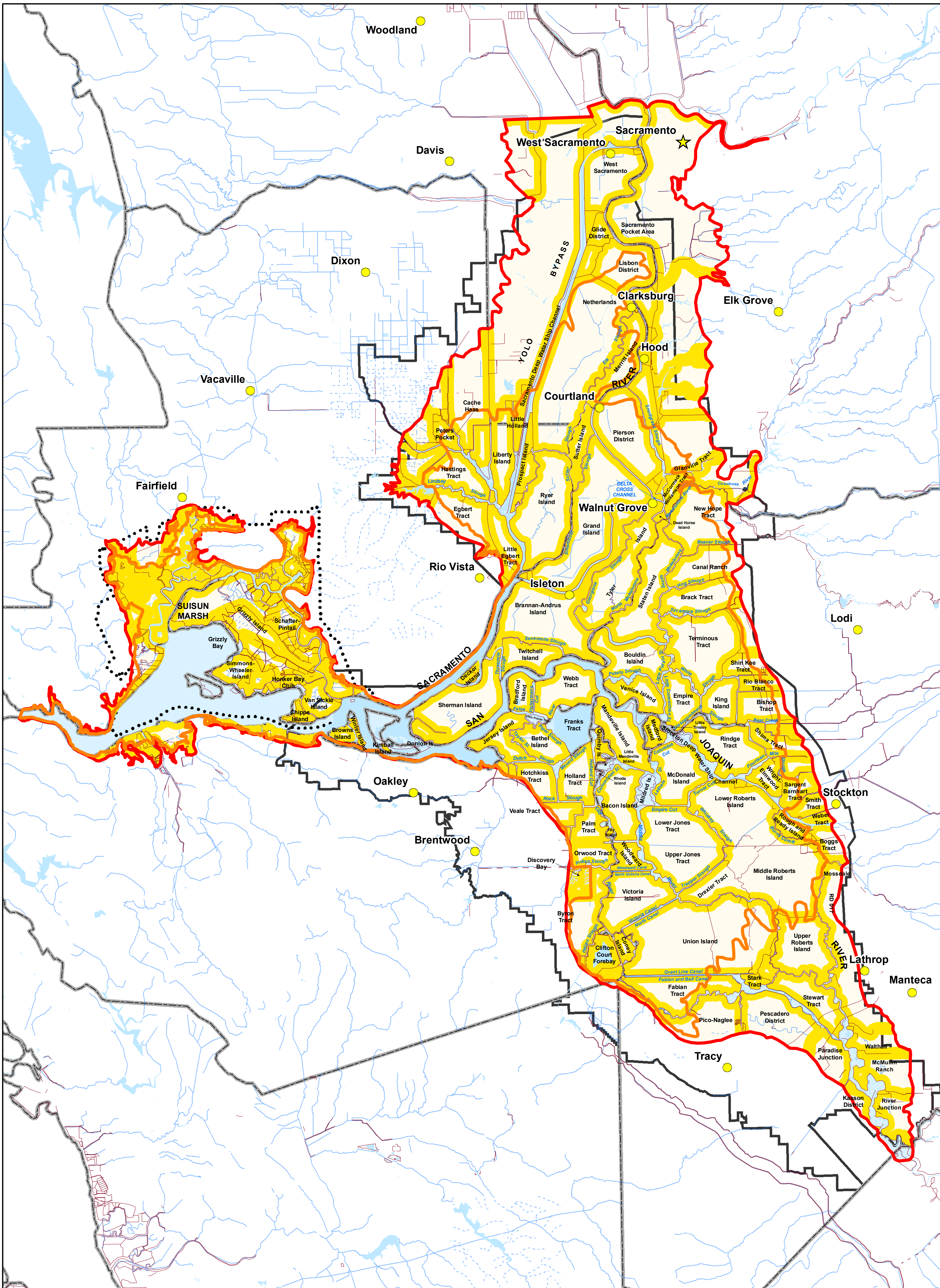
DRMS

26815431

MHHW and 100-Year Flood Boundaries

Figure 5-11

URS Corporation P:\GIS\GIS_Project_Files\MXD\Current Working Documents\Infrastructure\Floodplains+1 ft and subsided surface\4-1 MHHW and 100-year flood boundaries.mxd Date: 2/28/2007 12:49:32 PM Name: dhwrigh0



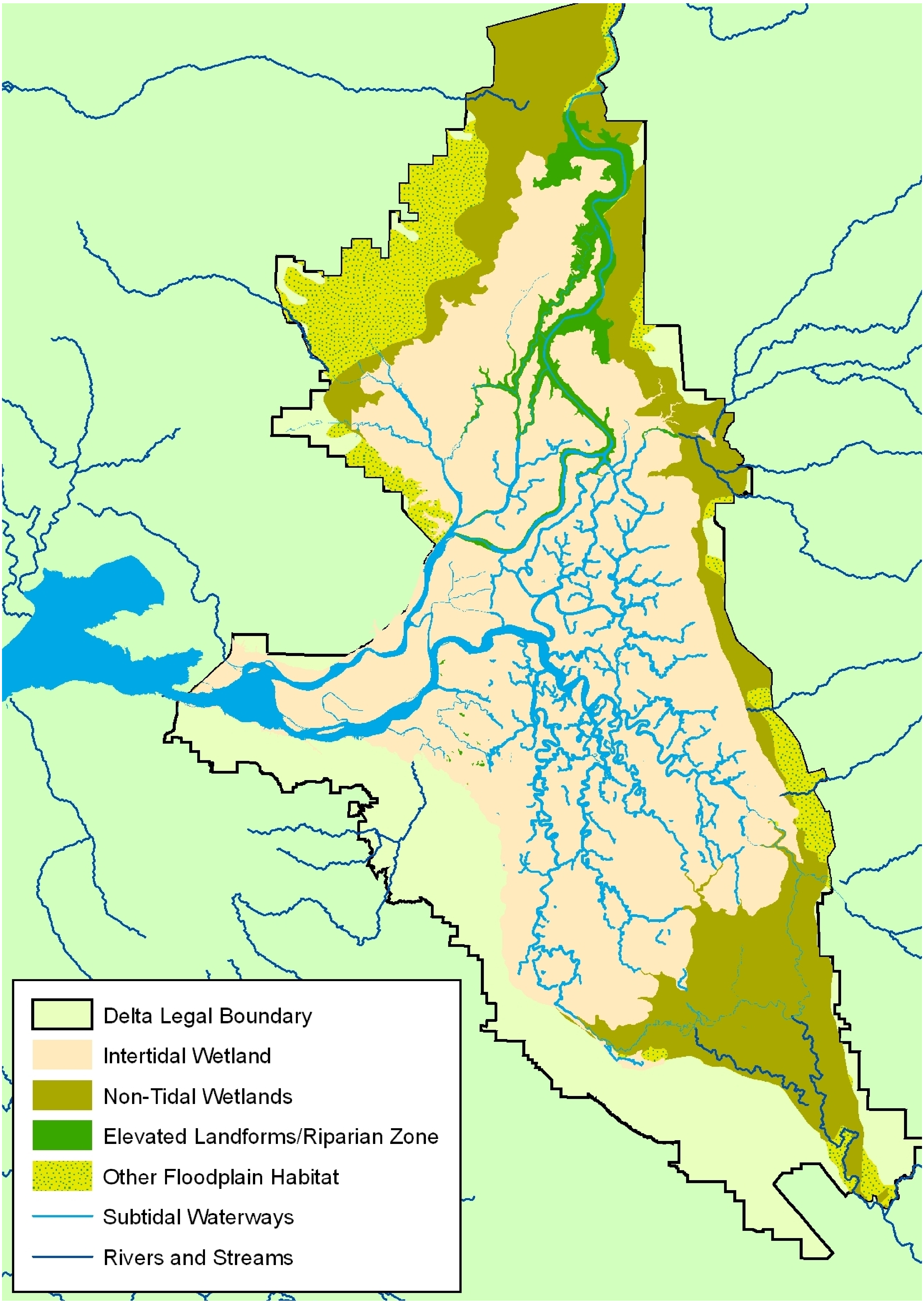
Legend

- Scour Zones
- Levees
- MHHW Boundary
- 100-Year Floodplain Boundary
- Intermittent canal, ditch, aqueduct, stream, river, or wash
- Perennial canal, ditch, or aqueduct; stream, river; reservoir
- CA Water
- CA Counties
- Legal Delta
- Suisun Marsh

0 5 10 Miles

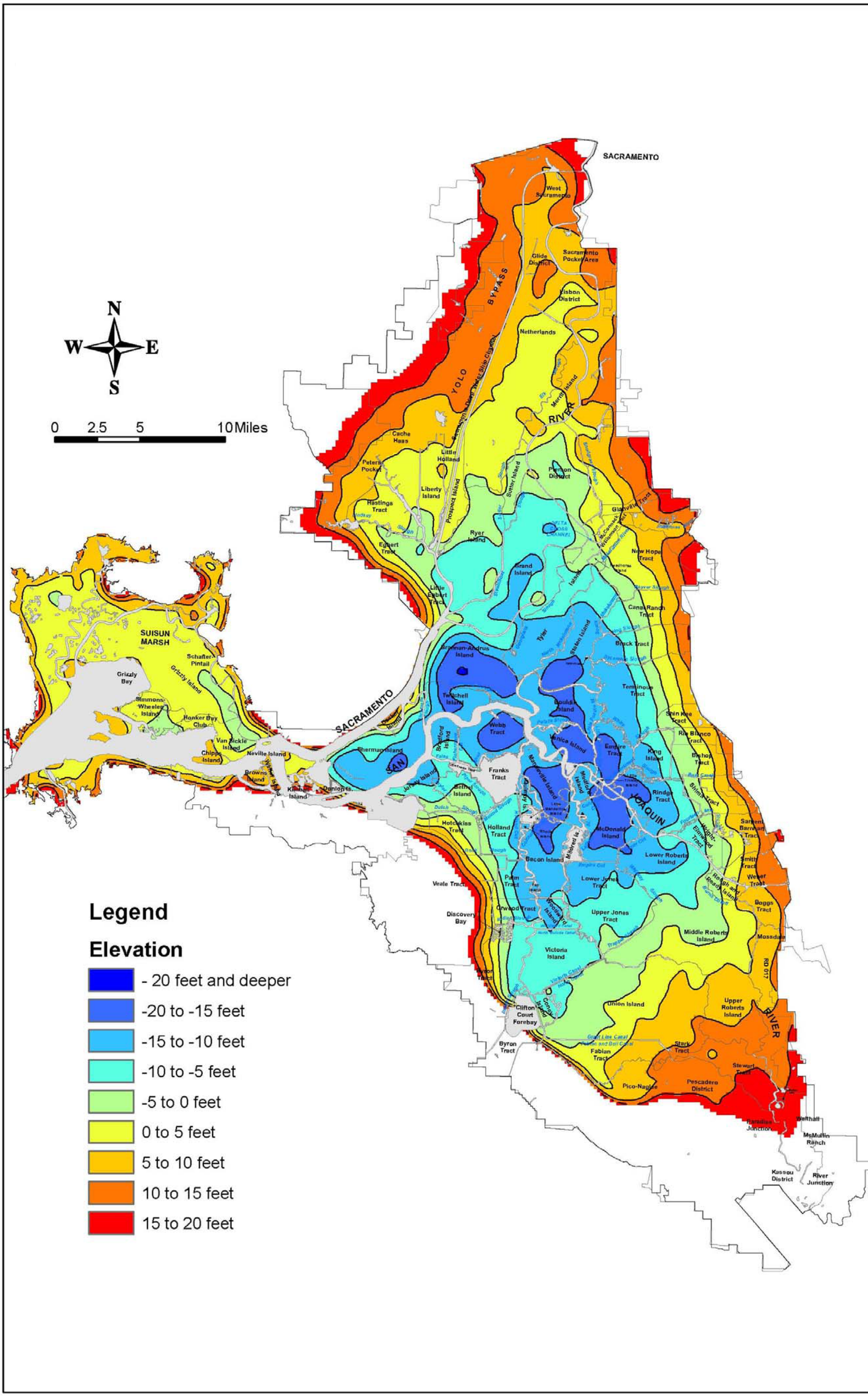
URS	DRMS 26815431	Scour Zones	Figure 5-12

URS Corporation P:\GIS\GIS_Project_Files\MXD\Current Working Documents\Infrastructure\tech_memo_R1_01050714-2 Scour Zones.mxd Date: 1/5/2007 11:44:43 AM Name: smlewis0



From: PWA, Draft Technical Memorandum - Geomorphology
Source: Bay Institute, 1998

URS	DRMS	Map of Historic Delta Habitats	Figure 5-13
	26815431		



URS	DRMS 26815431	Surface Elevation Map	Figure 5-14